Nonglacial Surficial Processes during the Early and Middle Wisconsinan Substages from the Glaciated Allegheny Plateau in Ohio[1]

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ABSTRACT. A review of the literature suggests that nonglacial surficial processes may be inferred from sites in Ohio of early through middle Wisconsinan age. These sites are not distributed uniformly and are identified by having post-Illinoian positions and nonfinite radiocarbon ages (that is, greater than 34,000 years). Organic deposits and paleosols of this age are comparatively common in the lowlands of southwestern Ohio, and the period is known to have experienced both warm and cool climates because some deposits contain oak, ash, and beech fossils, whereas others yield spruce. However, comparatively little evidence of this age has been found on the northwestern edge of the Allegheny Plateau in northeastern Ohio.

One remarkable exception is a site in a gravel pit in Garfield Heights in Cuyahoga County. This site provides an extensive record of weathering, pedogenesis, colluviation, loess deposition, and cryoturbation from this time, and is where an accretion gley, derived from an older paleosol, may have been deposited during the early Wisconsinan substage. Cryoturbated loess overlying the gley has a minimum age of 27,000 years in its upper part; its pollen suggests a boreal climate. An overlying loess, having a different provenance, was deposited from 24,000 to 27,000 years ago and contains pollen and insects that represent an open boreal environment.

A finite radiocarbon date on wood in sand and gravel from a depth of 74 m near London, Ohio, implies that fluvial baselevels were significantly lower before the late Wisconsinan substage. A deeply entrenched drainage system may have caused geomorphic instability of the landscape during this time and inhibited development and preservation of soils.

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INTRODUCTION

Deposits representing the early and middle Wisconsinan substages (oxygen isotopes stages 3-5d) are very rare in northeastern Ohio. Ice volume curves suggest that there was insufficient ice volume to have glaciated much of the midwestern United States during this time (Clark and Lea 1986, Clark and others 1993). As a result of this and other evidence, glacial events originally interpreted to have occurred during this time (Dreimanis and Goldthwait 1973, White and others 1969, White 1982, Fullerton 1986, Totten and Szabo 1987, Szabo 1987) have been reassigned to the Illinoian glaciation (Dreimanis 1992, Szabo 1992, Szabo and Totten 1995, Szabo 1996, Dreimanis and Lamothe 1996). Reassignment of tills to the Illinoian glaciation (Table 1) has left a large time period almost unrepresented by glacial deposits on the northwestern edge of the Allegheny Plateau.

The best record for this underrepresented period is found in the southwestern part of Ohio (Hall 1992, Lowell and Brockman 1994). Goldthwait (1958) grouped radiocarbon dates from wood found in outcrops in southwestern Ohio into three categories based on age. These groups included wood older than 34,000 years, wood dated between 16,000 and 34,000 years, and wood younger than 16,000 years. Wood from the first group is older than the late Wisconsinan substage, and Burns (1958) concluded that the wood submitted for dating by Goldthwait (1958) represented trees from two different climates. Spruce wood from Kirkwood in Shelby County (Fig. 1) and Gahanna in Franklin County suggests a cold climate, whereas oak, beech, and ash from Northampton in Clark County and oak from Germantown in Montgomery County indicate a warm climate. These wood types represent trees which may have grown at any time from the Sangamonian interglaciation to the late Wisconsinan substage and suggest that there were warm and cool periods during this time.

Because very little wood has been found in deposits on the glaciated Allegheny Plateau in Ohio, other lines of evidence are required to reconstruct geologic events during the Sangamonian through middle Wisconsinan time interval in this part of Ohio. The purpose of this paper is to review evidence for some of the geologic processes operating on the landscape during this period, including weathering, pedogenesis, colluviation, cryoturbation, loess deposition, and entrenchment of late Illinoian drainages. This evidence will be supported by a few available radiocarbon dates and data from Garfield Heights, Ohio.

WEATHERING AND PEDOGENESIS

Most evidence for Sangamonian weathering and pedogenesis is found in southwestern Ohio (Lowell and Brockman 1994), but this paleosol is also preserved at scattered locations along the glacial boundary. Quinn and Goldthwait (1985) recognized a Sangamonian soil preserved between the Illinoian Rainsboro Till and late Wisconsinan tills in Ross County in south-central Ohio (Fig. 1). Steiger (1995) discovered deeply weathered

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TABLE 1

Correlations of lithologic units in northeastern Ohio (modified from Szabo 1992)

Time		Eastern Scioto Lobe	Killbuck Lobe	Cuyahoga Lobe	Grand River Lobe
					Ashtabula Till
	Port Bruce Stade	Hiram Till	Hiram Till	Hiram Till	Hiram Till
Late Wisconsinan		Hayesville Till	Hayesville Till	Lavery Till	Lavery Till
	Erie Interstade				
	Nissouri Stade	Navarre Till	Navarre Till	Kent Till	Kent Till
Middle Wisconsinan through Sangamonian					
		Northampton Till	Northampton Till	Northampton Till	not found
Illinoian		Millbrook Till	Millbrook Till	Mogadore Till	Titusville Till
		Gahanna Till	not found	not found	Keefus Till
		Chesterville Till	not found	not found	not found

Illinoian outwash gravels (Wolfe and others 1962) having pedogenic clay translocated to a depth 3 m in Fairfield County (Fig. 1). In their discussion of terraces, Kempton and Goldthwait (1959) mention deep soil development on the Illinoian terraces along the Scioto and Hocking valleys in central Ohio. Additionally, gravels of these terraces are leached of carbonates to a depth of 5 m. Frolking (1988) described Illinoian outwash gravels cemented by pedogenic carbonate to a depth of 6 m in Licking County, along the eastern limit of the former Scioto lobe (Fig. 1).

Although Sangamonian pedogenesis is generally evident on Illinoian outwash terraces near the glacial boundary, outcrops of paleosols are rare elsewhere on the plateau. This suggests that the hillslopes and uplands may have been undergoing erosion during Sangamonian through middle Wisconsinan time (Follmer 1983). Moreover, ice may have removed any evidence of soil formation in areas glaciated by late Wisconsinan ice because either Illinoian and Wisconsinan tills are in sharp contact, suggesting erosion, or they are separated by thin beds of silt, sand, or gravel that may suggest additional erosion by subglacial meltwater. Apparent weathering zones at the contact between these different age tills are very thin and are most likely produced by groundwater flow and not surficial weathering.

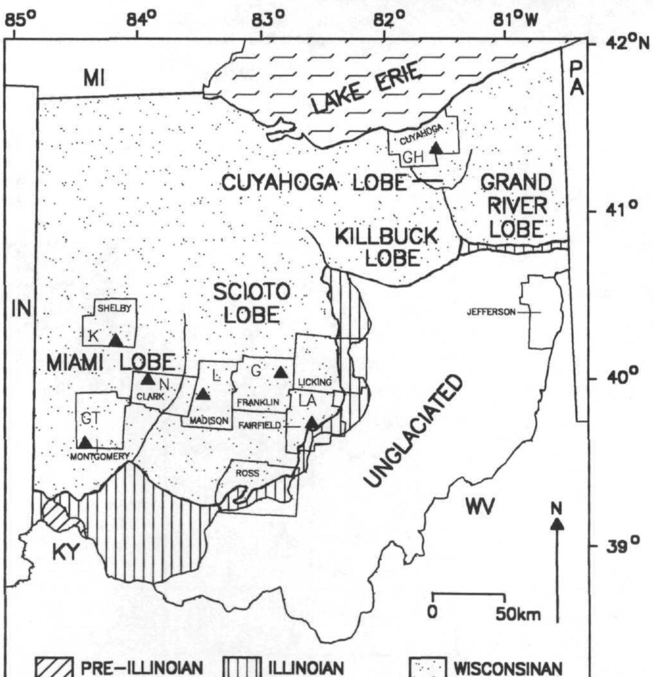

FIGURE 1. Generalized glacial map of Ohio showing approximate locations of counties and sites mentioned in this paper. Sites are: K, Kirkwood; GT, Germantown; N, Northampton; L, London; G, Gahanna; LA, Lancaster; GH, Garfield Heights.

COLLUVIATION

In a strongly eroding landscape, slope processes may produce and transport a continuous supply of colluvium. Amba and others (1990) studied a slope in the nonglaciated plateau in Jefferson County (Fig. 1) and determined that soils formed in multiple parent materials consisting of bedrock residuum, coarse colluvium, and a mixture of fine colluvium and late Wisconsinan loess. Clay mineral abundances suggest that there were alternating periods of stability allowing soil formation to begin and periods of instability during which incipient soil profiles were eroded.

Other evidence of slope activity is found in the valley of Rocky Fork Creek near Gahanna, Ohio (Goldthwait 1992). The gravel separating the Gahanna Till, currently assigned to the Illinoian (Szabo and Totten 1995), from overlying late Wisconsinan tills was originally interpreted as Lockbourne outwash from a middle Wisconsinan glaciation (Dreimanis and Goldthwait 1973) that deposited the Gahanna Till. A spruce log within the gravel having a radiocarbon age of 46,000 ± 2,000 B.P. (GrN-3219) was used to support the earlier age assignment. Because the elevation of the gravel is higher than those of the Lockbourne outwash in adjacent valleys and the imbrication suggested an eastern source, Goldthwait (1992) reinterpreted the gravel as an alluvial fan deposit largely derived from a local bedrock.

CRYOTURBATION AND LOESS DEPOSITION

Features ascribed to cryoturbation have been identified at few locations on the Allegheny Plateau. Cryoturbation is interpreted to have occurred during the Wisconsinan stage and is generally recognized by the presence of loess mixed into underlying deposits. In a study of surficial deposits beyond the glacial boundary, Amba and others (1990) showed that the upper parent material consists of fine colluvium mixed with loess; this mixing was most likely produced by cryoturbation. Farther north, Everett and others (1971) and Frolking (1988) discovered cryoturbation features in a mixed zone between loess and Illinoian outwash gravels in eastern Licking County (Fig. 1).

Loess deposition definitely occurred beyond the Wisconsinan limit of glaciation during late Wisconsinan ice advances. Steiger (1995) found late Wisconsinan loess covering Illinoian deposits along the glacial boundary in Fairfield County (Fig. 1). Quinn and Goldthwait (1985) noted the presence of a loess cover which must have formed prior to the construction of the Reesville and Farmersville moraines about 17,000 years ago. It is difficult to determine the exact age of deposition along the glacial boundary; some loess may have been deposited in the latter part of the middle Wisconsinan substage, whereas additional loess was deposited during the late Wisconsinan substage. The time intervals between the episodes of loess deposition may have been insufficient to cause differences in soil development especially in a cool climate.

CASE STUDY: GARFIELD HEIGHTS, OHIO

Effects of these geologic processes are best illustrated in a section at Garfield Heights, Ohio, in southeastern Cuyahoga County (Fig. 1); this site has been investigated periodically for over 40 years. Although the section is becoming overgrown and covered by colluvium, the following units are exposed from old to young (Fig. 2): gravel having a truncated paleosol, accretion gley, lower loess, upper loess, lacustrine clays and silts, and late Wisconsinan tills. Fullerton (1986) reviewed the age assignments of these units based on data of this pit and another pit that is no longer open. A full discussion of the age of the Garfield Heights till and other older units is included in Szabo (1992) and is beyond the scope of this paper. The part of the section below the late Wisconsinan tills (Fig. 2) is important in this study, and data from these units will be used to illustrate processes operating before late Wisconsinan glaciation and to interpret paleoclimates at this site.

Stratigraphy

Studies of the stratigraphy at this site include those of White (1953, 1965, and 1968), Dreimanis (1971), Berti (1971), Fullerton and Groenwold (1974), Fullerton (1986), Szabo and Miller (1986), Miller and Szabo (1987), and Szabo (1992). Section A (Fig. 2) is the only place where Illinoian gravels and the Sangamonian paleosol developed on them are exposed beneath the accretion gley. The paleosol is dark reddish brown, contains iron and clay concentrated around pebbles, and is interpreted to be a truncated B-horizon of a well-drained soil (White 1968). Matrix clay content (% <2 mm) decreases with depth into the underlying gravel, and fine-carbonate content (% <0.074 mm) increases with depth until the gravel is cemented by carbonate (Fig. 3). Clay mineralogy of the paleosol consists of vermiculite, montmorillonite, and an illite-montmorillonite intergrade (Szabo and Miller 1986), but the amount of vermiculite and the degree of illite degradation decreases with depth, causing the ratio of illite to kaolinite and chlorite to increase (Fig. 3).

A variable, yellowish-brown to greenish-gray, platy to

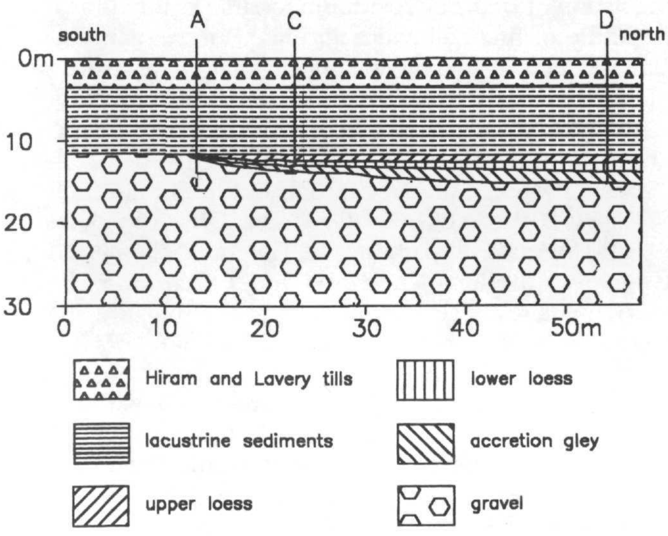

FIGURE 2. Cross section from Garfield Heights, Ohio (modified from White 1968). A, C, and D are sections measured and analyzed by Szabo and Miller (1986).

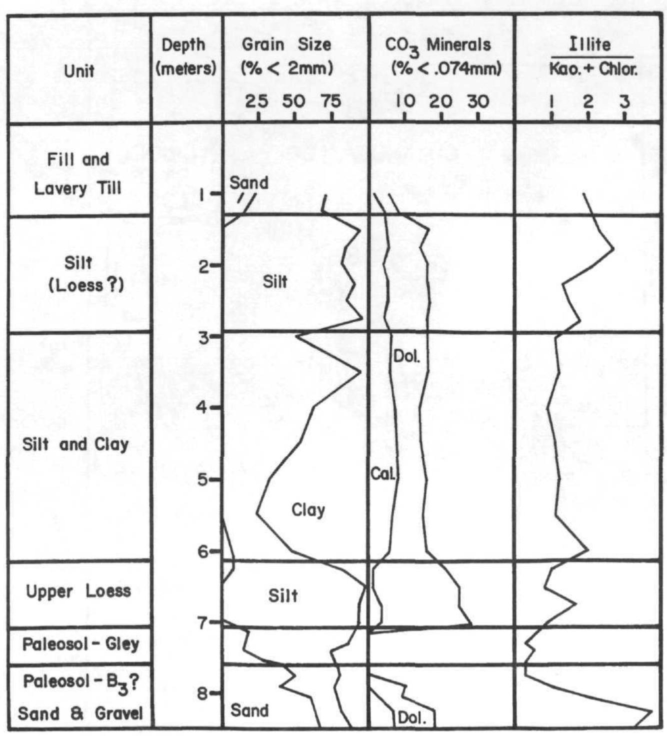

FIGURE 3. Laboratory analysis of section A (Fig. 2).

blocky to massive accretion gley overlies the Illinoian gravels. Its grain size varies within and between sections (Szabo and Miller 1986) but it becomes finer grained in a downslope direction to the north. Pebble bands and gravel pockets containing rotten pebbles are common; joints are coated with abundant iron and manganese stains that are also concentrated in layers within the gley. The lack of carbonates (Fig. 3) is the only consistent aspect of the gley. X-ray diffractograms of the clay mineralogy of the accretion gley are classified into two groups: one group contains definable vermiculite, montmorillonite, and illite-montmorillonite peaks, and the other group consists of very broad peaks of heterogeneous swelling material (Willman and others 1966).

Yellowish-brown, friable lower loess overlies the accretion gley (Fig. 2) and was originally assigned to the Altonian (early or middle Wisconsinan) substage (White 1968). This loess averages 2% sand, 85% silt, and 13% clay across the width of the exposure. It is generally devoid of carbonates except at section D (Fig. 2) where a gray, weakly calcareous layer containing slightly more than 5% dolomite is present in its middle part (Szabo and Miller 1986). The presence of montmorillonite, illite-montmorillonite, vermiculite, and degraded illite show that this loess has been weathered. A zone, containing disseminated organic matter 10 cm below the contact of this loess with the upper loess, may represent an incipient soil and has a radiocarbon age of 27,390 ± 350 B.P.(ISGS-1949) that establishes a minimum age for its deposition (Szabo 1992). A wood fragment also from this loess has a radiocarbon age of 28,195 ± 535 B.P.(K-361-3). This loess may have been deposited during the early or middle Wisconsinan substage (Dreimanis 1992; Dreimanis and Lamothe 1996). Berti (1975) found involutions consisting of downfolded bedding accentuated by iron staining in the upper loess, suggesting cryoturbation, whereas Fullerton (1986) thought that the upper part of this loess had been deformed glaciotectonically by a very early late Wisconsinan advance, but he did not associate this advance with any till in the immediate area.

The upper loess at this site is light olive brown to light grayish brown, friable, and calcareous and contains snails and wood fragments (Szabo and Miller 1986). It is slightly more silty than the underlying loess and averages 2% calcite and 18% dolomite. This loess is less weathered than the lower loess and contains vermiculite, illite, and some montmorillonite.

Light brownish-gray, plastic, platy to blocky, Fe- and Mn-stained, laminated lacustrine silts and clays overlie the upper loess (Fig. 2). This unit contains more calcite than the upper loess (Fig. 3), and it has a variable clay mineralogy consisting of unaltered chlorite and illite alternating with intergrades of illite-montmorillonite and chlorite-vermiculite (Szabo and Miller 1986). The clay content generally increases downward towards the bottom of the unit, but near the contact, the unit is noticeably coarser and contains more sand, snails, and wood fragments. Miller and Wittine (1972) suggested that the bottom of the lacustrine silts and clay was a colluvial zone which can be traced across the width of the exposure and is also found at the base of the laminated sediments in other pits in the area (Szabo and Miller 1986). Detrital wood fragments lay parallel to the laminations, and several radiocarbon dates for wood in this unit average about 24,000 yrs.

Other late Wisconsinan deposits include a silt, possibly of eolian origin (Szabo and Miller 1986), and tills. The Kent Till crops out along the edges of the old, filled pit to the south of this site and along Interstate 480, and consists of lodgement and supraglacial meltout facies. The younger Hiram and Lavery tills were deposited over the Kent Till south of the pit and over possible eolian silt in the pit.

Fossils

Many investigators have collected and identified fossils in some units at the site (Leonard 1953, Coope 1968, Berti 1975, Miller and Wittine 1972, Morgan and others 1982). Their results can be summarized as follows: the accretion gley, the oldest unit, contains some reworked Devonian and Mississippian spores. The lower loess contains spruce, pine, and oak pollen and spores of *Selaginella* and *Lycopodium*, and both aquatic and terrestrial snails are present. Sedge, pine, and spruce pollen and spores of *Selaginella* are found with terrestrial snails and insects in the upper loess. Detritus identified in the colluvial part of the laminated silts and clays contains not only wood of spruce and larch but also other plant macrofossils such as spruce needles, *Dryas* leaves, and sedge and violet seeds. Spruce, pine, oak and sedge pollen occur throughout this unit, whereas spores of *Selaginella* are only found in its upper part. Terrestrial snails and insects also are found in these laminated sediments.

Depositional History and Environments

The geometry (Fig. 2), and physical, mineralogical, and paleontological characteristics of the stratigraphic units at Garfield Heights suggest an environment in which a hill was cyclically eroded, and sediment was transported and deposited at the base of the slope in a colder than present climate during the early and middle Wisconsinan substages. Assuming that the truncated paleosol represents a well-drained soil that developed on a hill of Illinoian gravel during the Sangamonian interglaciation (White 1968, Szabo 1992 and 1996, Dreimanis and Lamothe 1996), slope processes eroded a long, gentle slope into a basin to the north (Fig. 2). Colluvial material was eroded from the upper part of the paleoslope, transported downslope, and deposited at the foot- and toe-slopes as an accretion gley. Erosion may have occurred in cyclical episodes because there is some evidence of layering, accentuated by Fe- and Mn-staining, in the accretion gley, and its clay mineralogy alternates between heterogeneous swelling material and better-organized clay minerals. This suggests that slope processes may have eroded the upper part of the paleosol first and then removed less weathered sediment; soil formation would occur during periods of stability between erosional events. Some x-ray diffractograms of the accretion gley are comparable with those of the paleosol developed in the underlying gravel.

The lower loess was deposited after the accretion gley in a severe boreal climate (Berti 1971 and 1975) during the early through middle Wisconsinan substages. The overall weathered appearance of this loess coupled with its general lack of carbonates and its degraded and expandable clay minerals suggest that it was derived from a weathered source or weathered at the surface for a long period. The source material may have been the weathered colluvium on the nearby landscape. The minimum age of 27,000 years for the organic zone in the upper part of the lower loess indicates a short period of stability that was ended by another episode of loess deposition before being cryoturbated to produce involutions. Aquatic gastropods in this unit are indicative of local ponds during loess deposition (Leonard 1953).

The late Wisconsinan ice advance was preceded by eolian deposition which deposited the upper loess from 24,000 to 27,000 years ago. The source of this loess contained more carbonates and illite than that of the lower loess. Vermiculite, derived from chlorite, and montmorillonite suggest that there was also a local component of weathered material as a source. Terrestrial gastropods, pollen, wood, and insects from the upper part of this loess suggest a boreal environment having scattered trees (Morgan and others 1982, 1983).

About 24,000 years ago before the arrival of late Wisconsinan Kent ice, substantial hillslope erosion was renewed causing loess, sand, altered clay minerals dominated by degraded illite, and organic detritus to be deposited at the base of the slope. This colluvial episode was followed by deposition of laminated silts and clays in a shallow lake or pond. The clay mineralogy contains altered clay minerals suggestive of inwashing of a local weathered component. The plant fossils suggest forest-tundra conditions (Berti 1971), and the gastropods and insects indicate that the pond most likely dried up during the summer (Coope 1968). Thus, the laminated silts and clays, possibly composed of loess and colluvium, may have also been cyclically deposited during the onset of the late Wisconsinan glaciation.

DRIVING FORCES

The examples cited in this paper show that dominant surficial processes during late Sangamonian through middle Wisconsinan time included weathering, pedogenesis, loess deposition, cryoturbation, and colluviation. Although the inferred cyclicity of these processes represented by the depositional record may have been partially driven by climate, fluvial erosion may have also influenced landscape development. A predominantly southward-flowing drainage was inherited from Illinoian meltwater streams (White 1982), but there is little evidence of the amount of relief on the post-Illinoian surface. Local baselevels can be estimated from Illinoian terraces, but they might not necessarily represent baselevels for the whole time between the Illinoian glaciation and late Wisconsinan glaciation.

Bedrock topography maps are of little use in determining baselevel and in defining the post-Illinoian drainage. Most of these maps show a complex arrangement of superposed and subparallel drainage systems. If all buried valleys are connected in an attempt to form a single drainage net, the result is an illogical, complex system of closely-spaced master streams. Therefore, bedrock topography maps represent a bedrock surface that has evolved during many episodes of fluvial and glacial erosion. Some buried valleys (Dove 1960), such as one in southwestern Licking County (Fig. 1) are completely filled with pre-Sangamonian deposits including thick sequences of Illinoian tills and underlying lacustrine sediments, whereas others (Wolfe and others 1962) in nearby Fairfield County (Fig. 1) contain at least 50 m of interbedded Wisconsinan tills and outwash.

The best estimate of baselevel during the Sangamonian through middle Wisconsinan substages in central Ohio comes from split-spoon samples from several test wells drilled at London, Ohio (Fig. 1). A wood fragment from sand and gravel of a channel eroded into lacustrine clays at a depth of 74 m, has a radiocarbon age of 28,390 ± 330 B.P.(ISGS-3224). This date and the geometry of the channel suggest that post-Illinoian streams were wider and more deeply incised into the landscape than their post-Wisconsinan counterparts that now drain an area having 10 m of local relief. Another wood fragment from the base of a late Wisconsinan till in southeastern Fairfield County (Fig. 1) has a radiocarbon age of 26,780 ± 430 (ISGS-3223) and implies that the Illinoian till surface was 37 m below the present surface. These estimates of pre-late Wisconsinan surface elevations are credible and supported by numerous sites in southern Michigan where organic matter deposited from 30,000 to 40,000 years ago is commonly found at depths of 20 to 80 m beneath the modern surface (Rieck and Winters 1982).

A low-elevation baselevel may be one of the driving forces in controlling geologic processes during the Sangamonian through middle Wisconsinan substages. A deeply entrenched drainage may have promoted active hillslope erosion that could have removed soils and produced colluvium during a time when the climate was becoming progressively colder. Evidence for these processes is fortuitously preserved at scattered locations on the Allegheny Plateau and provides a base for future research.

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